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SLIDES: The Use of Terrestrial Cyanobacteria for the Rehabilitation of Arid Soils: Not Just Another Good Idea

Timothy Flynn

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The Use of Terrestrial cyanobacteria for the Rehabilitation of Arid Soils: Not just another good idea



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It's Alive!

Along the trail, you will notice patches of dark sand on the soil through which creepers in the desert are able to move. It is called "creeping sand" and is the source of the "creeping sand" that you see on the trail.

These sand-dwelling plants are able to move the desert sand through the soil, creating a network of tunnels and allowing the sand to move in and out.

This sand is so fine that it can move through the soil at night.

Please don't walk on it. Stay on trails.



Le sol vit!

Le long des sentiers, vous remarquerez des zones de sable noir qui se déplacent à travers le sol. C'est ce qu'on appelle le "sable rampant" et c'est la source du "sable rampant" que vous voyez sur le sentier.

Ces plantes qui vivent dans le sable sont capables de déplacer le sable à travers le sol, créant un réseau de tunnels et permettant au sable de se déplacer en et out.

Cette sable est si fin qu'il peut se déplacer à travers le sol la nuit.

Il est donc important de ne pas marcher sur ce sable.

Restez sur les sentiers.

Der Boden lebt!

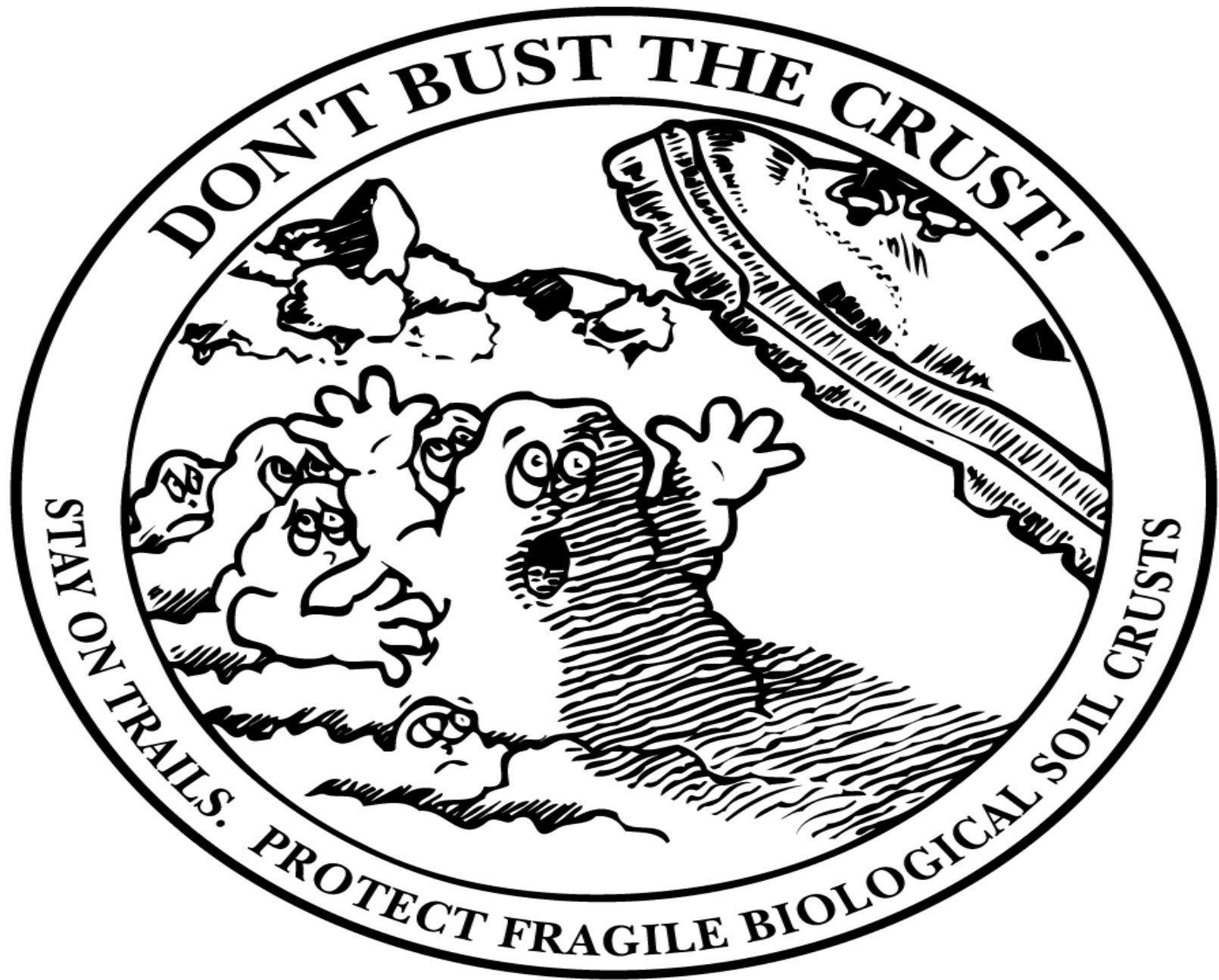
Entlang des Pfades werden Sie sehen, dass sich schwarzer Sand durch den Boden bewegt. Dies ist das sogenannte "Kriechsand" und es ist die Quelle des "Kriechsand", den Sie auf dem Pfad sehen.

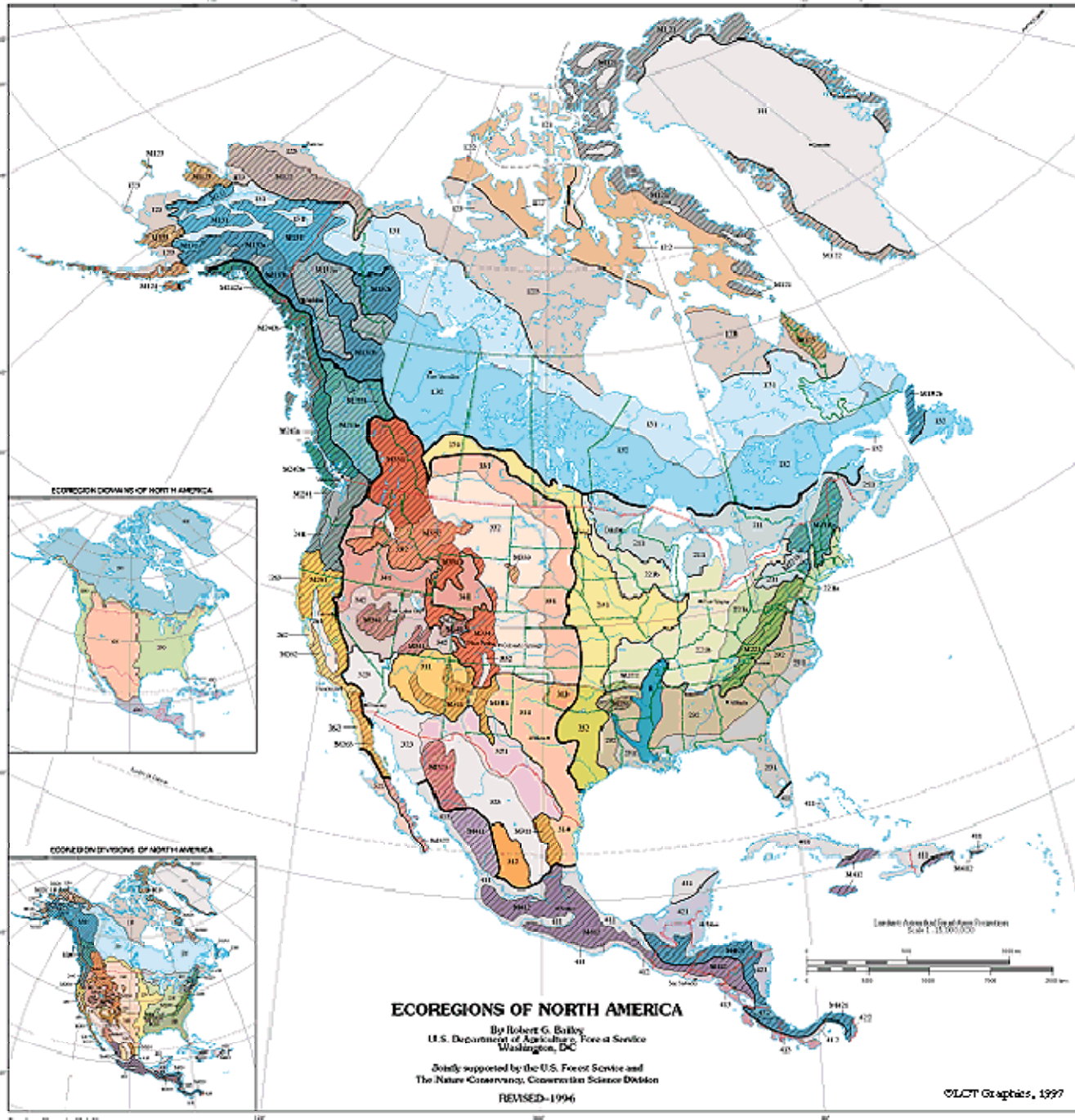
Diese Sandbewohnenden Pflanzen sind in der Lage, den Sand durch den Boden zu bewegen und so ein Netzwerk von Tunneln zu schaffen, das es dem Sand ermöglicht, ein- und auszuweichen.

Dieser Sand ist so fein, dass er sich nachts durch den Boden bewegen kann.

Es ist daher wichtig, nicht auf diesem Sand zu gehen.

Bitte bleiben Sie auf den Pfaden.





35% of world is
arid ($= 5.2 \times 10^9$ ha)

40% of US

Evaporation
exceeds
precipitation

Ecoregion	Annual precipitation (mm)	Moisture: Season/Form	Mean annual temperature range (°C)	Vegetation type
Hot Deserts				
Sonoran	75 – 255	Summer/rain Fall/rain	15 – 24	Mixed thorn scrub
Mojave (low elevation)	50 – 150	Winter/rain	10 – 24	Scrubland
Mojave (High elevation)	150 – 610	Winter/rain	3 -10	Scrubland
Chihuahuan	205 – 245	Summer/rain	10 – 18	Scrubland
Cool Deserts				
Colorado Plateau	205 – 510	Winter/snow Spring/rain Summer/rain	4 – 13	Scrubland Woodland
Great Basin	130 – 490	Winter/snow Spring/rain	4 -13	Sagebrush steppe Salt-desert shrub
Columbia Basin	260 – 635	Winter/rain Spring/rain	4 – 14	Perennial grassland
Great Plains	490 – 740	Spring/rain Summer/rain	4 – 18	Prairie grassland
Coastal Chaparral				
California Chaparral	175 – 635	Winter/rain	15 – 18	Chaparral grassland

Background

- **Arid environments are dominated by microbial communities** (Cyanobacteria, algae, Lichens, Fungi, Bacteria, and Mosses)
- **Cyanobacteria**
 - ◆ Photosynthetic, Azototrophic (fix nitrogen)
 - ◆ Active when wet, dormant when dry → Desiccation tolerant
 - ◆ 70% of ground cover, 99% of nitrogen input
 - ◆ Cyanobacteria are first to colonize new substrates.



What's in a name? Biological Soil Crusts (BSCs)

- Also known as “cryptogamic soils”, “cryptobiotic”, “microbiotic”, or “microphytic” crusts
- Different from “Physical crusts”
- See www.soilcrust.org

Crust-Stabilized Slope



Slope Close-up

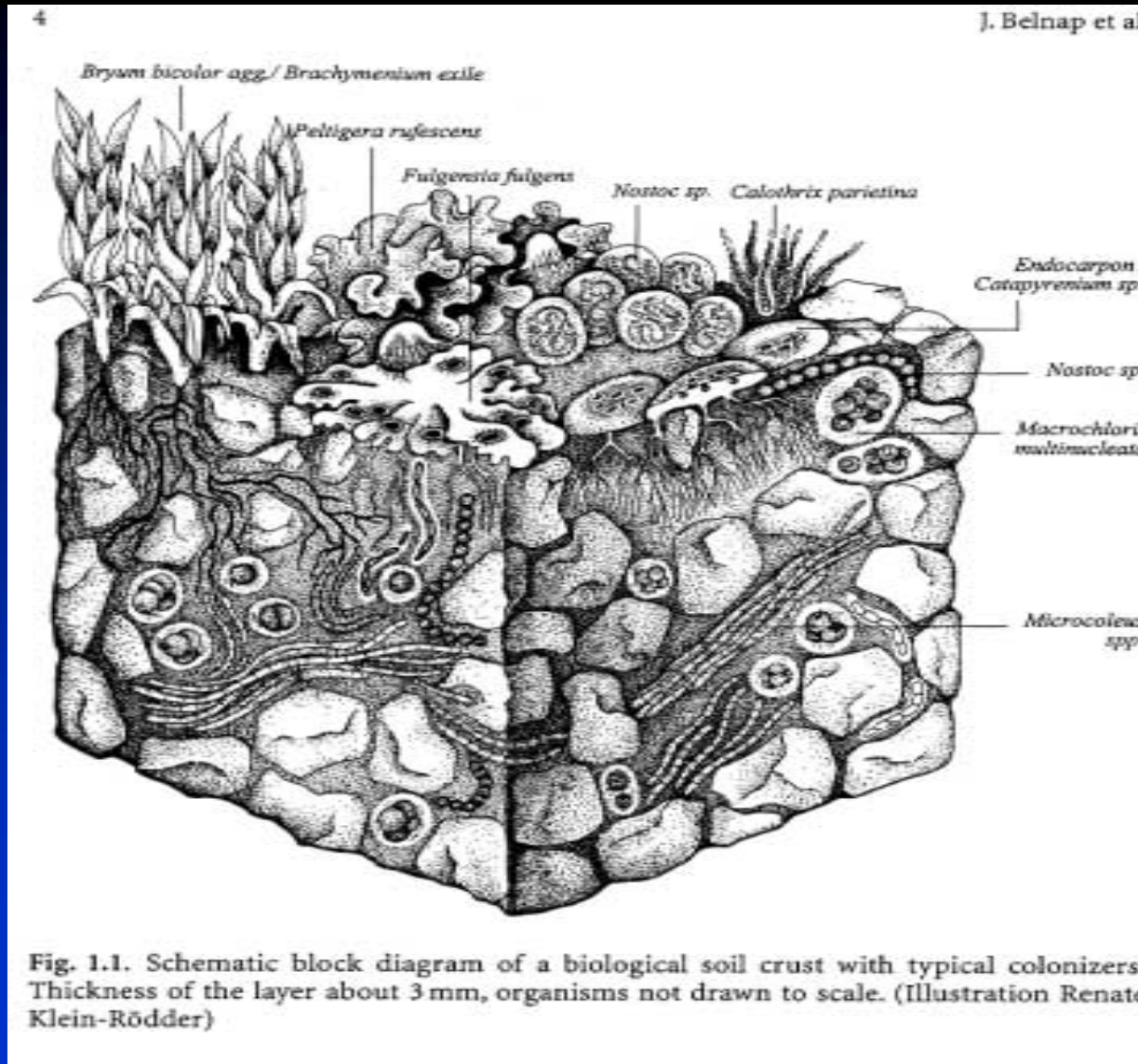




The BSC microbial community: “Terrestrial Pondwater”

- Cyanobacteria
- Lichens (cyanolichens and phycolichens)
- Fungi
- Bacteria
- Eukaryotic algae
- Bryophytes (mosses and liverworts)
- Protozoa (single celled animals)
- And a host of others

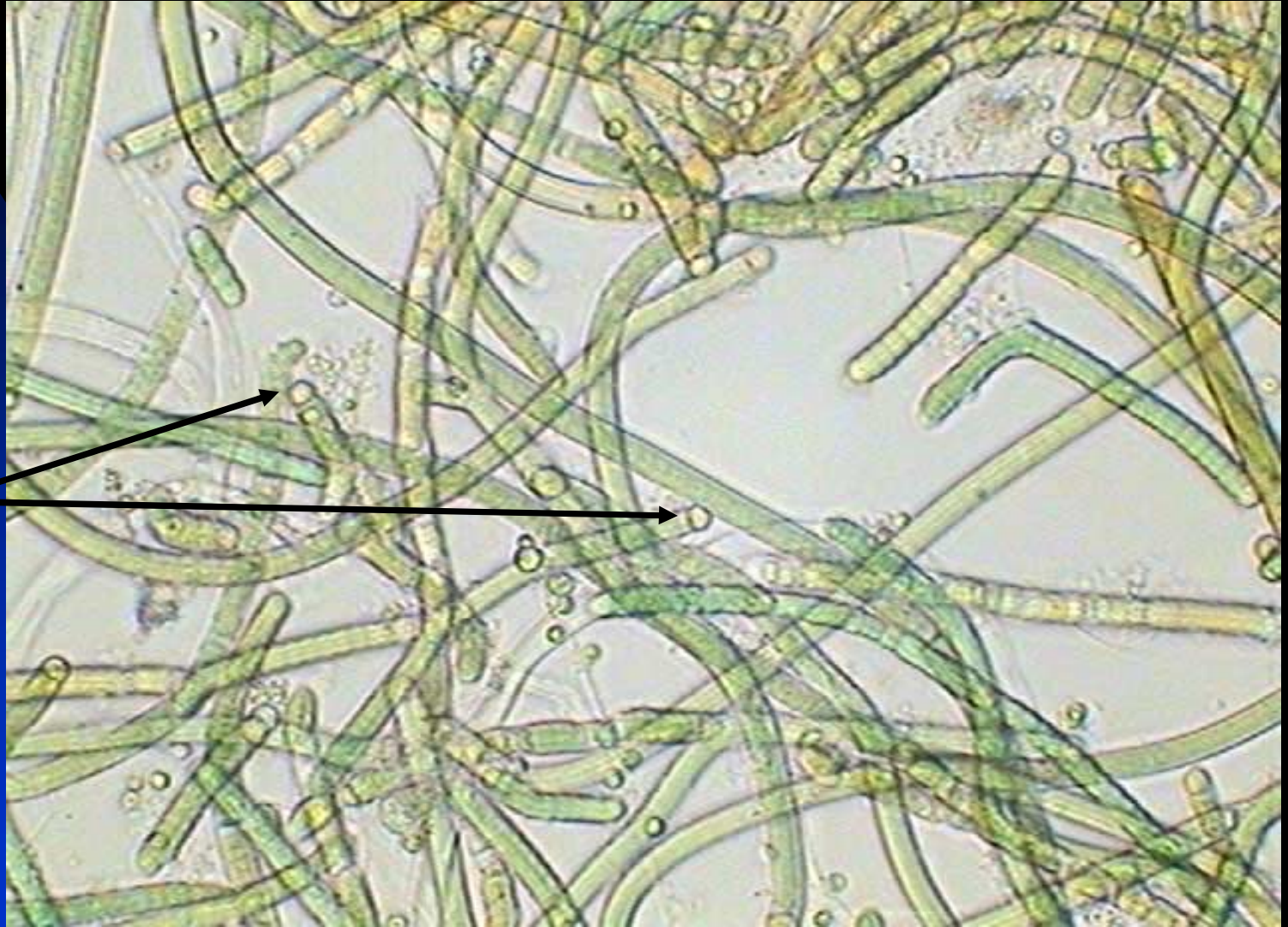
Soil Crust Community



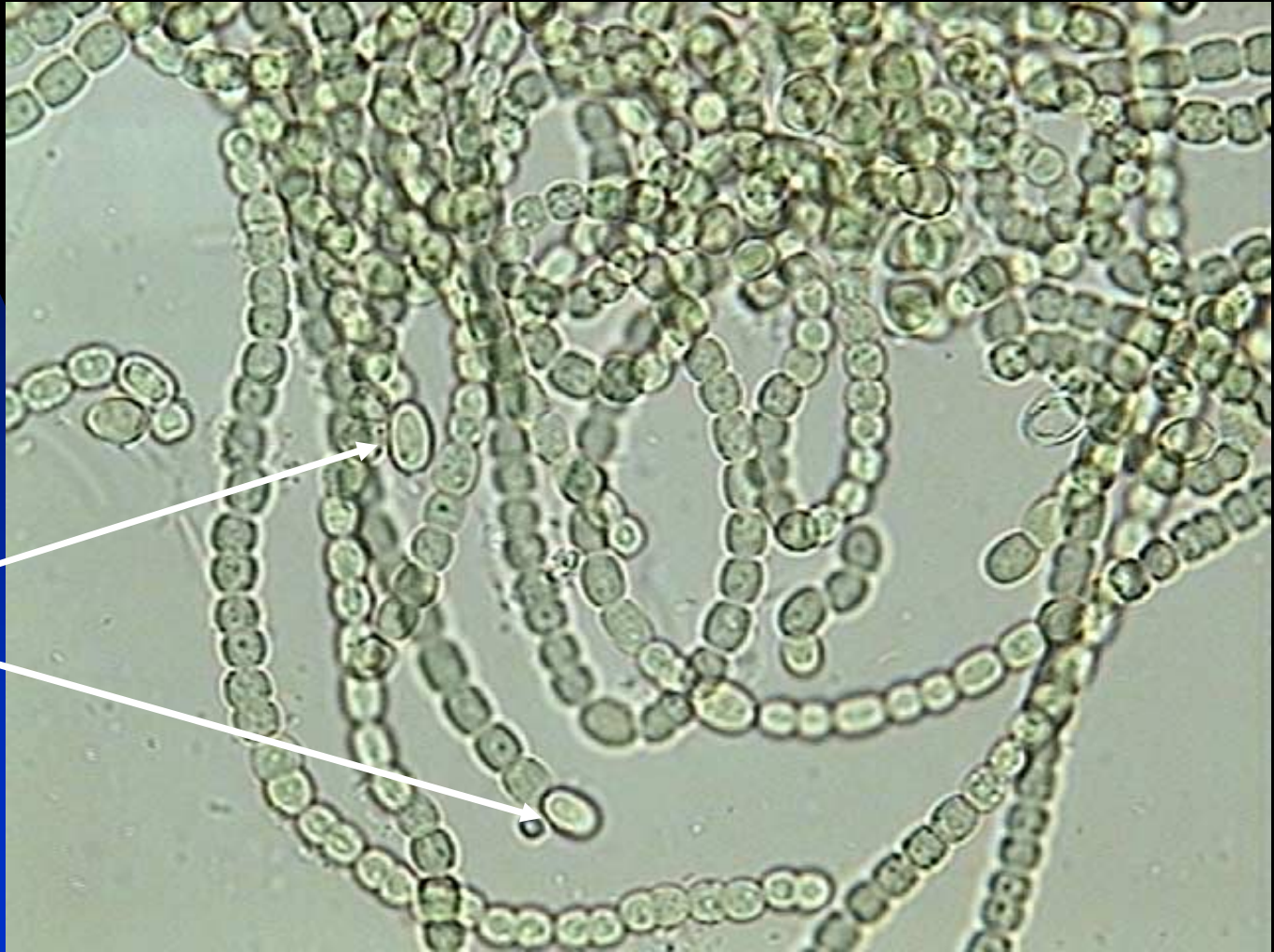
3 mm³

Tolypothrix sp.

Heterocyst



Trichormus sp. (=Anabaena)



Heterocyst

Nostoc colony



Lichens: Fungal-Algal Symbionts



■ Phycolichen:

- ◆ Eukaryotic “green” algal partner
- ◆ Stratified thallus



■ Cyanolichen:

- ◆ Prokaryotic cyanobacterial partner
 - ★ Nitrogen-fixing
- ◆ Non-Stratified gelatinous thallus



Collema tenax



BSC = TPS

(terrestrial pond scum)

Amoeba- 1000x



amoeba 1000x.avi

Hormogonia and *Vorticella*

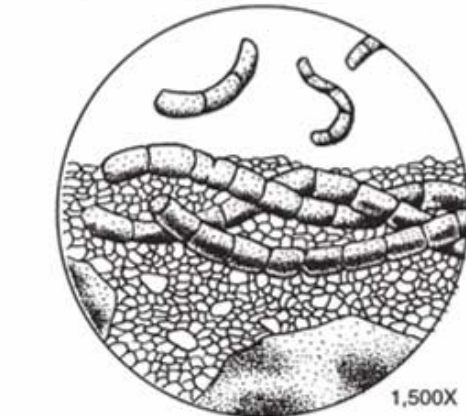
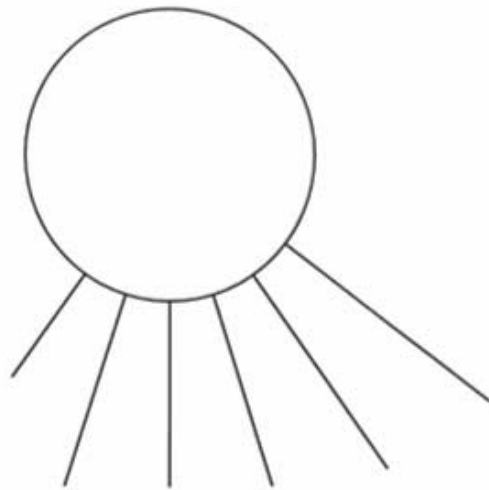


hormogonia and vorticella 1000x.avi

Vorticella – 1000x



vorticella 1000x.avi



Young Cryptos: 0 to 3 Years

Cyanobacteria float through air and fall to the ground, crawl across the surface, or are carried by bugs and animals. They remain on the surface to catch sunlight and photosynthesize for their life processes.



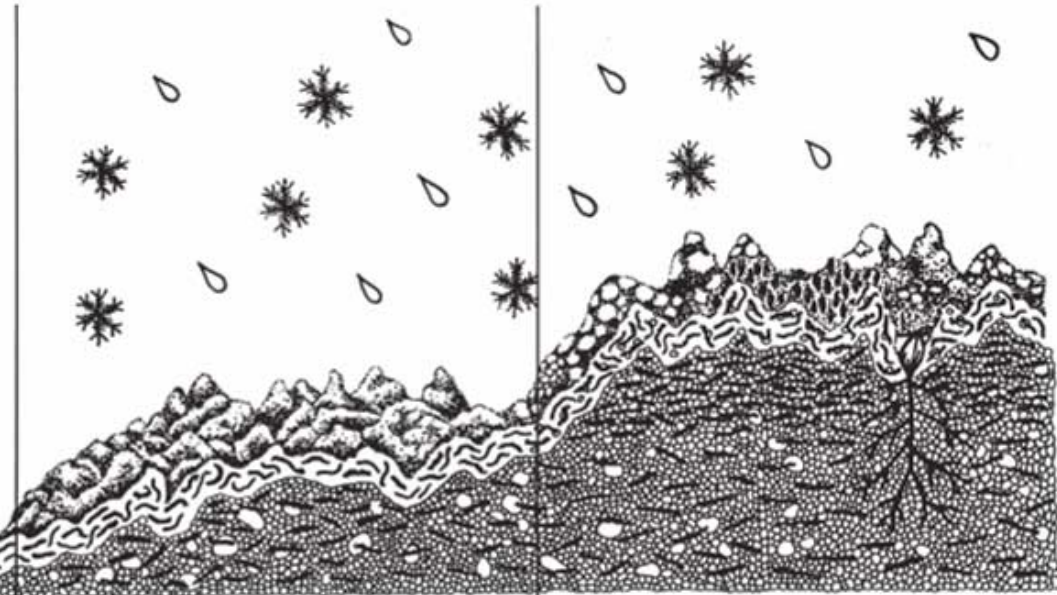
Mid-life Cryptos: 3 to 10 Years

Cyanobacteria secrete sticky sheaths that stick to sand particles. When buried by soil, the cyanobacteria move to the surface. With frost heaving, sheaths form a contorted surface.



Mature Cryptos: 10+ Years

Lichen, mosses, fungi grow on surface; water debris and seeds become entrapped in pockets, seeds root which further strengthen soil.



Crust-Mediated Erosion Control: What's holding the place in place?

- Up to 70% of the vegetative cover in deserts
- Slime covered filaments bind soil particles together
- Frost heaving in cool deserts → water infiltration
- Organic matter → water holding capacity
 - → Carbon Sequestration
- Creates mechanical barrier that prevents the establishment of exotic weeds (Cheat Grass)

Crust and Soil Fertility

- Secretes nitrogen ($10 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$)
- Chelates micronutrients
 - ◆ (Fe, Mn, Co, Ni, Zn, etc.)
- BSCs contribute soil organic matter:
 - ◆ Improves water holding capacity
 - ◆ Provides energy for bacteria and fungi
 - ➞ facilitates biogeochemical cycles

Working Photobioreactor



Coyote Gulch Demonstration Unit

CONFIDENTIAL





320 lbs (dry equivalent) of harvested biomass
ready for oil extraction

CONFIDENTIAL

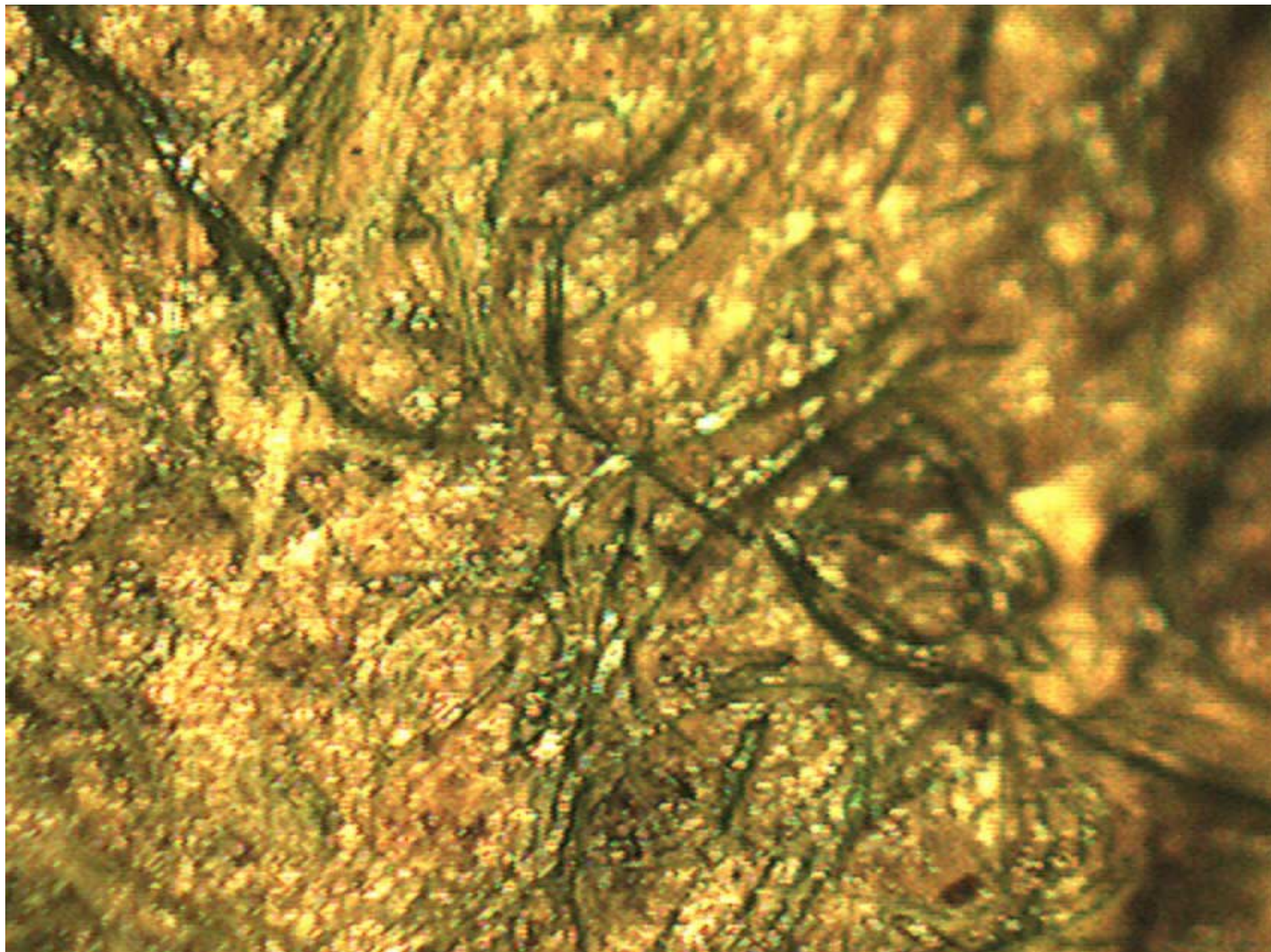


GeoDerm™

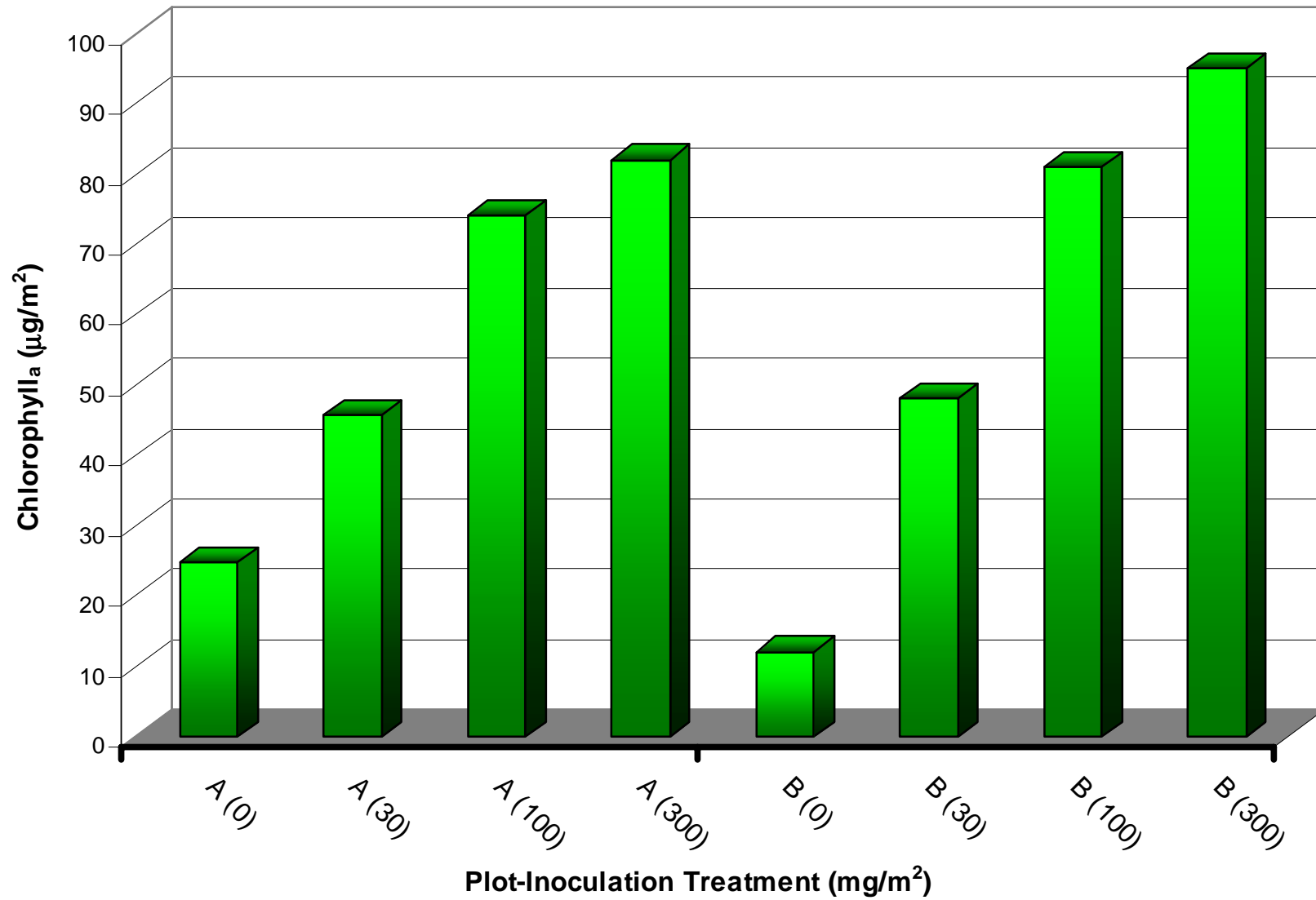


Home-made Crust (First Generation)

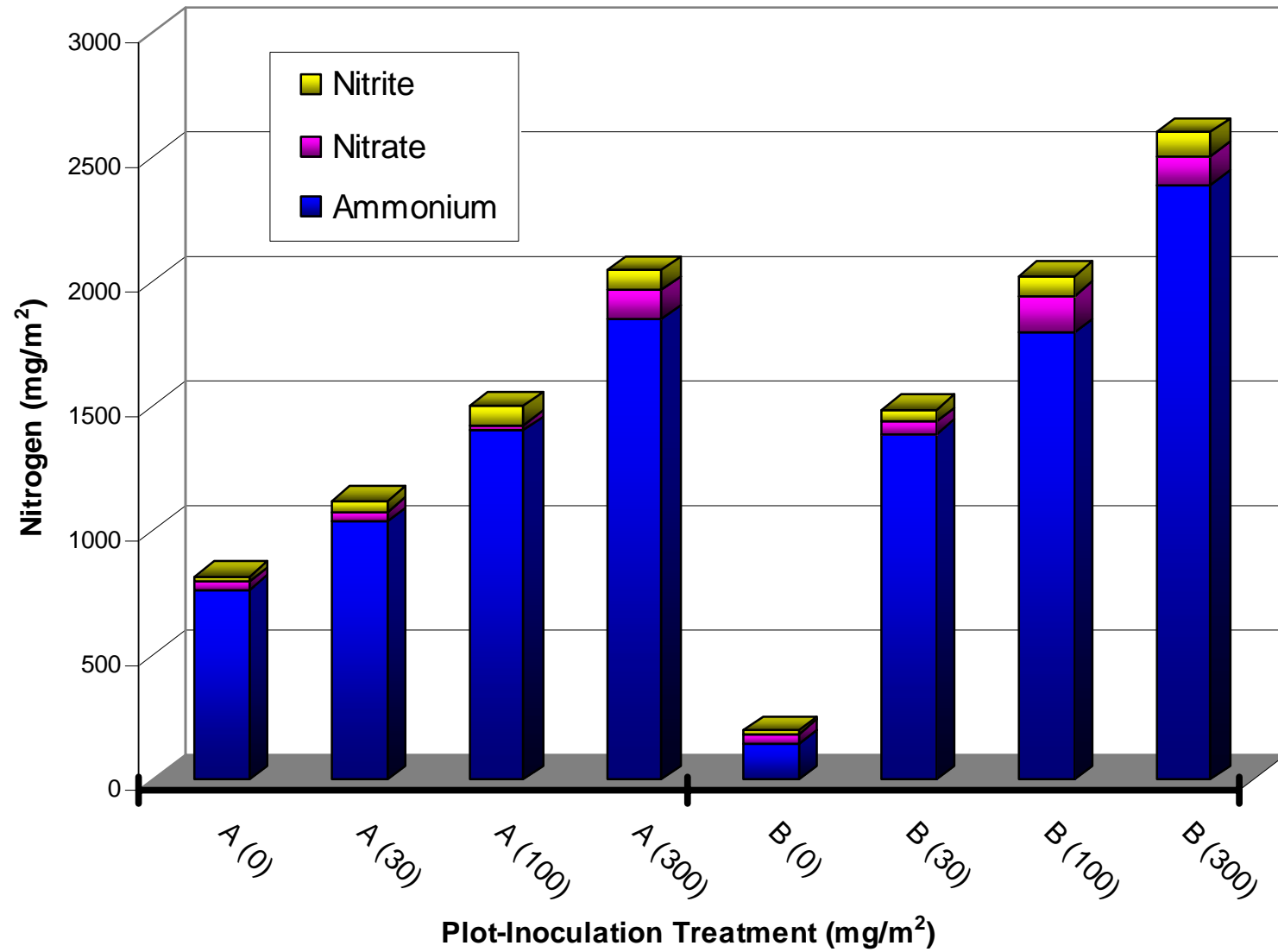




Soil Chlorophyll (18 Months)



Total Nitrogen (18 Months)

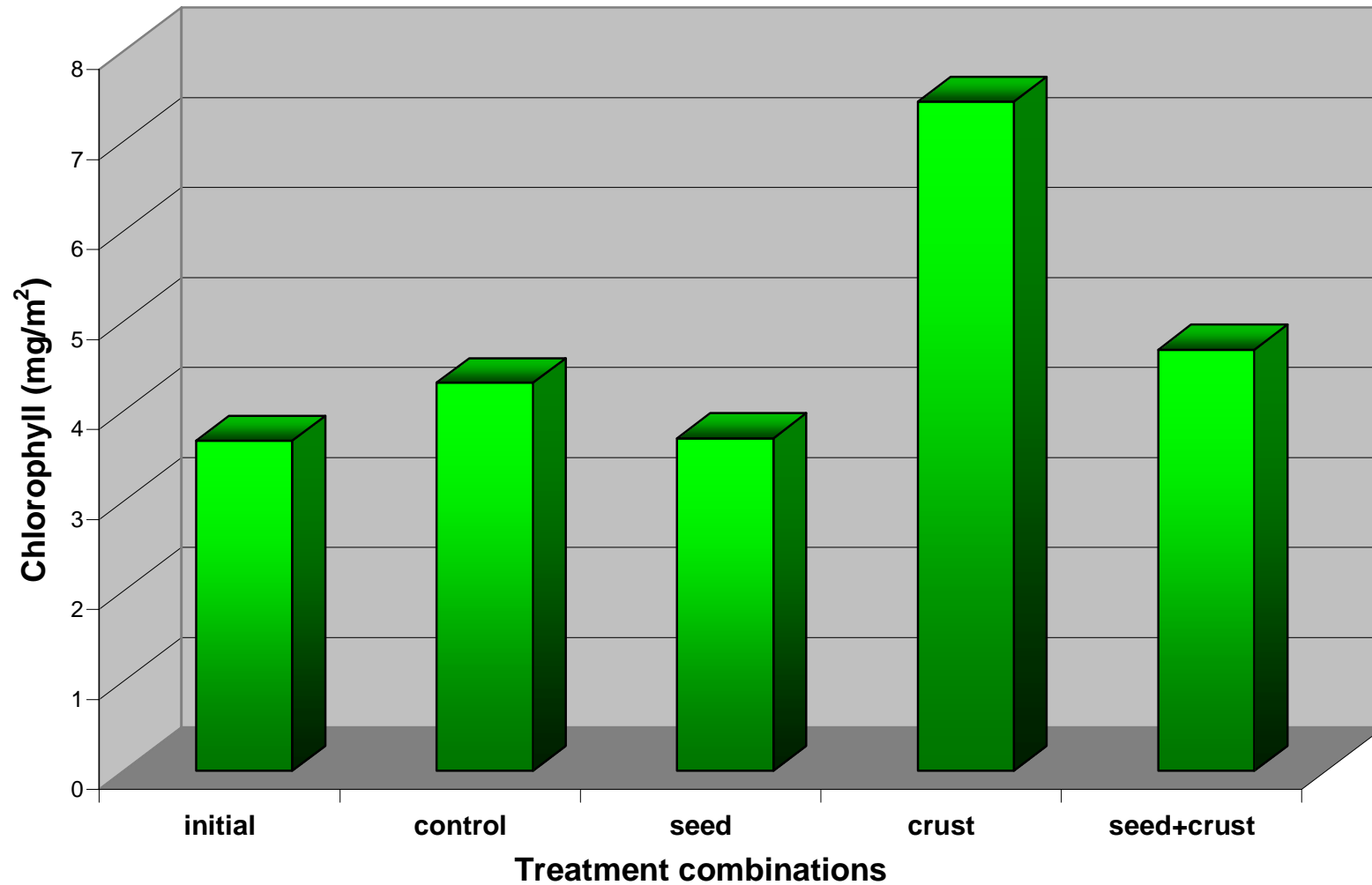




Norwood-
nost fire

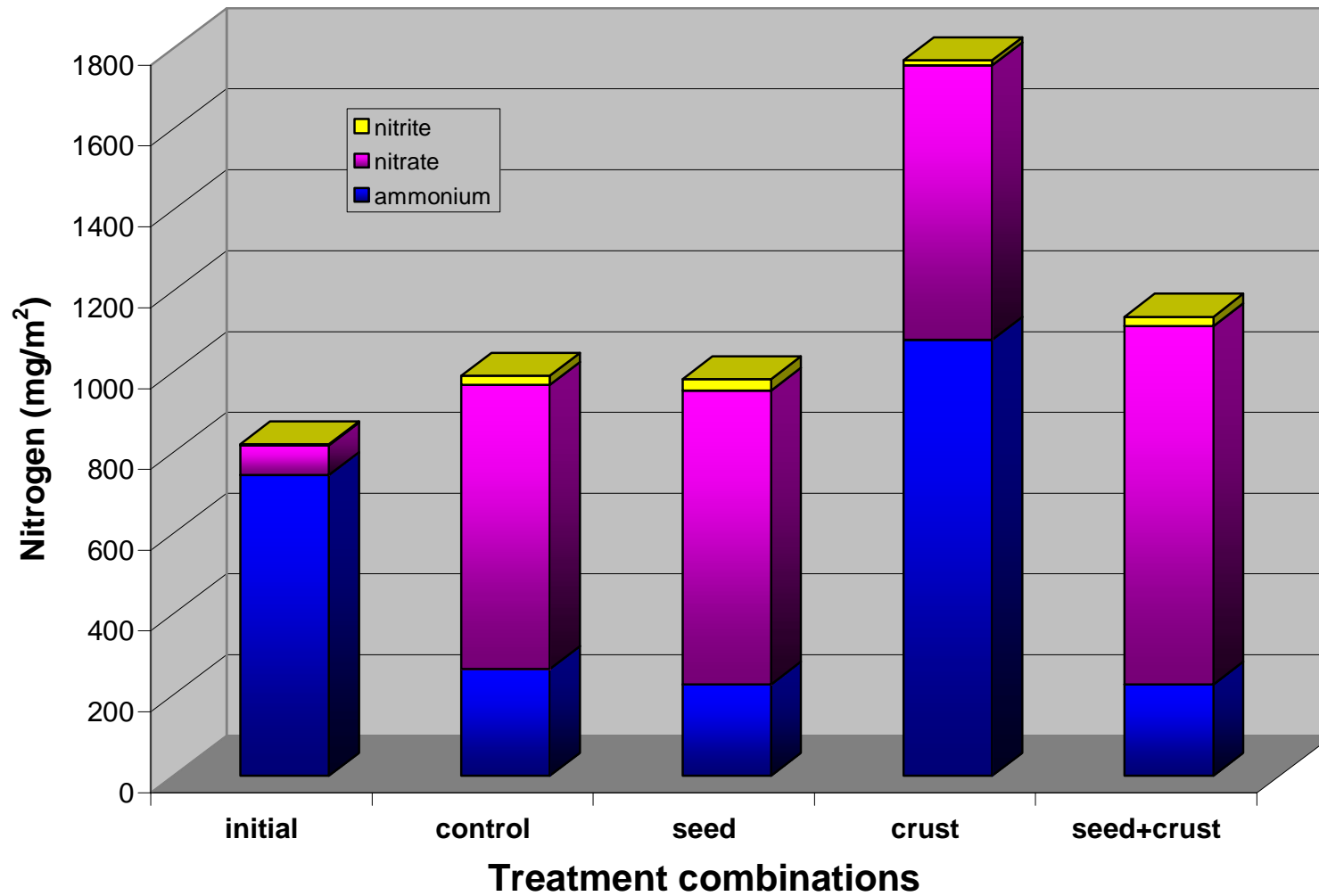
Norwood Post-Fire (6 months)

Figure 1: Soil Cholorophyll

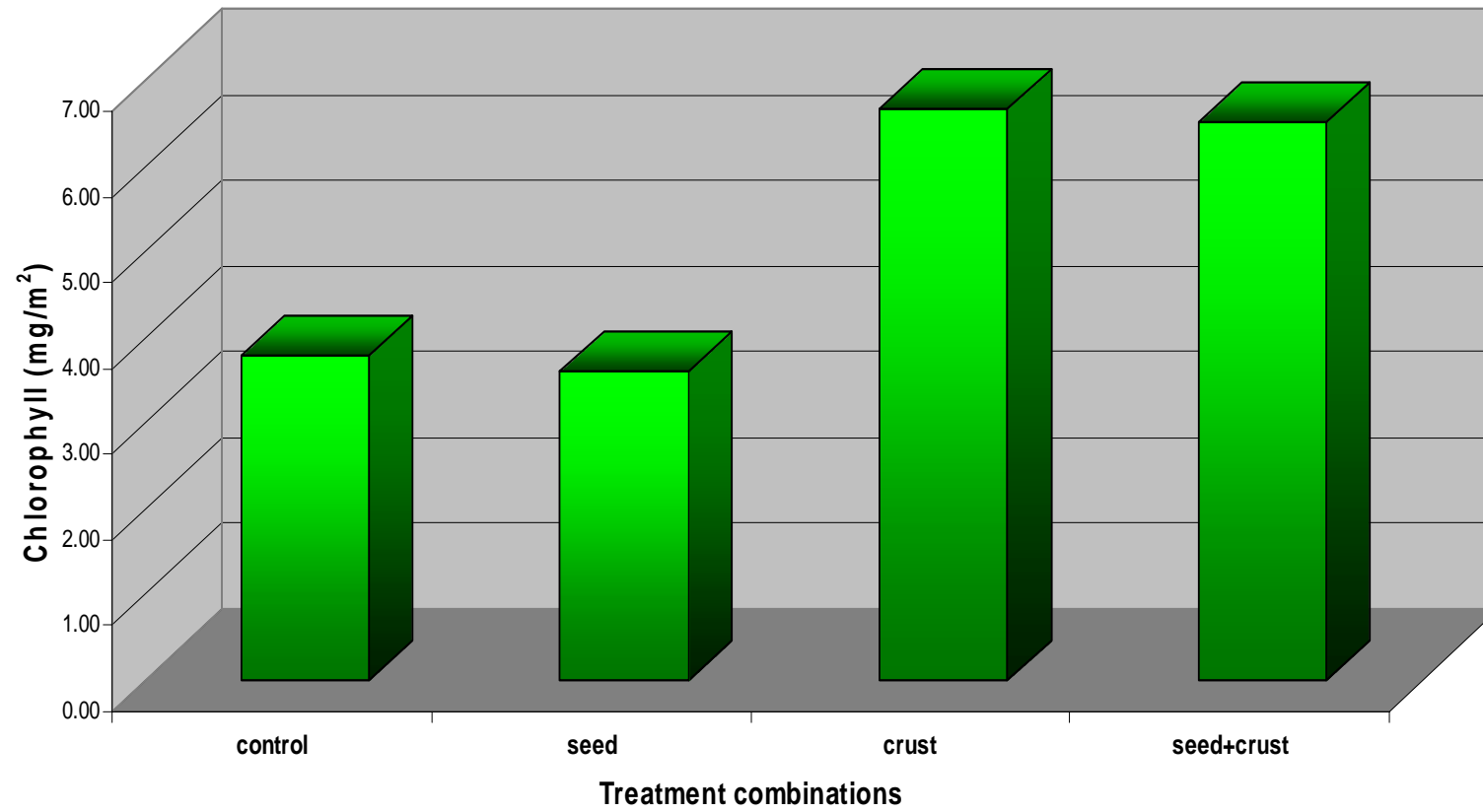


Norwood Post-Fire (6 months)

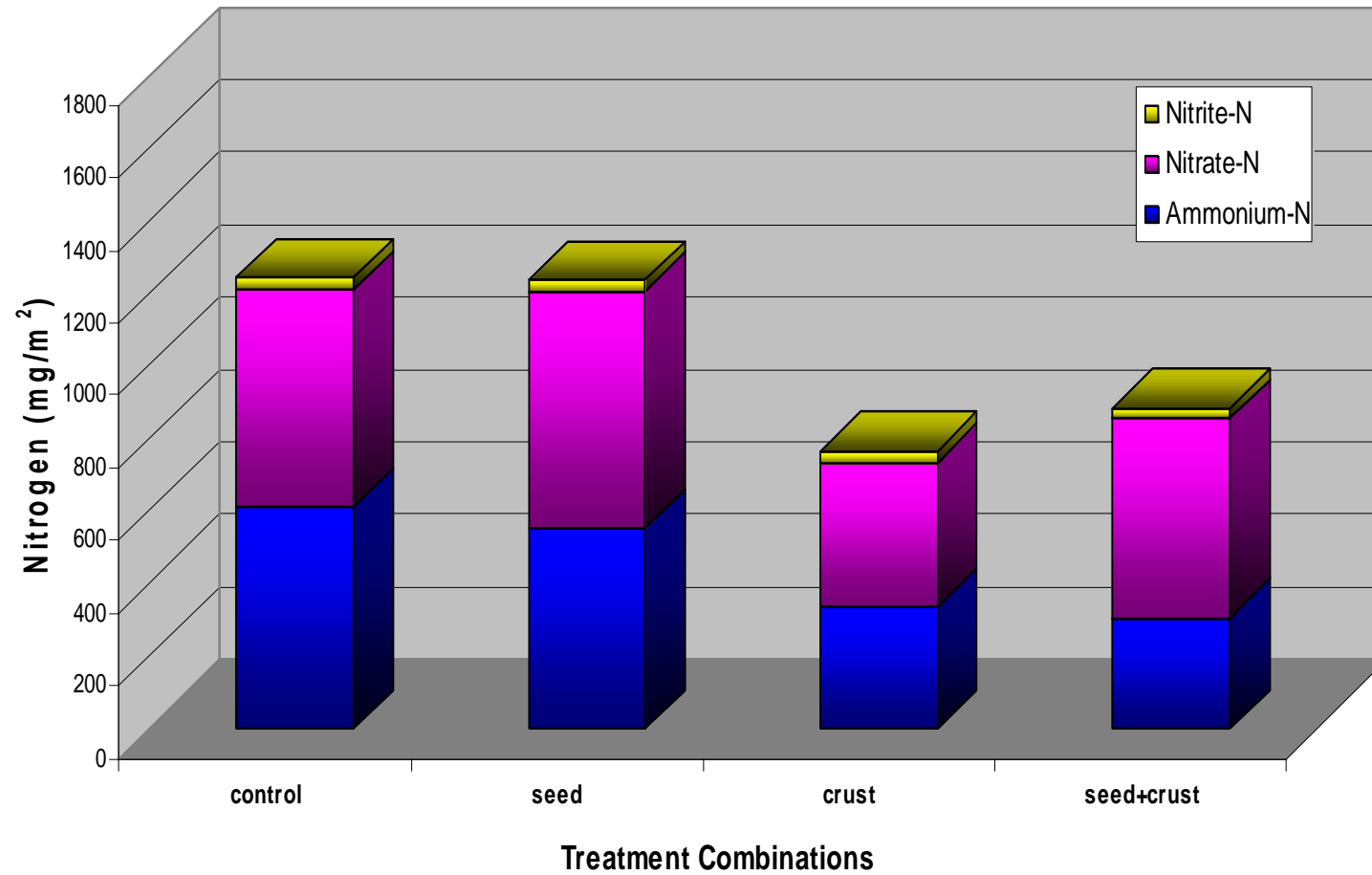
Figure 2: Soil Nitrogen



**Figure 2: Chlorophyll- 14 month total incubation
(winter interval)**



**Figure 4: Nitrogen- 14 months total incubation
(winter interval)**





EnCana

March
2009

Thank You

